Complete Three-Dimensional Bandgap in One-Dimensional Negative-Index Periodic Structures

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Negative-index (or left-handed) metamaterials with simultaneously negative real parts of dielectric permittivity and magnetic permeability can be used for novel applications, including enhanced sub-wavelength imaging. We reveal, for the first time to our knowledge, that a one-dimensional periodic structure with layers of negative-index material can possess, under certain conditions, *a complete three-dimensional bandgap* for both TE- and TM-polarized waves. In this case, the Green function characterizing radiation of a point source becomes exponentially localized because the electromagnetic waves cannot propagate through the structure at any angle. The existence of *one-dimensional structures made of transparent materials and possessing a complete three-dimensional spectral band gap* is a highly nontrivial and unexpected finding, which was not reported earlier. Our results are in a sharp contrast with all known properties of one-dimensional dielectric periodic structures, which can only possess partial spectral gaps that provide omni-directional reflection for a limited range of the incident angles. Indeed, light can always propagate through a dielectric structure due to coupling between guided modes supported by individual dielectric slabs, however we find that this tunneling mechanism can be suppressed in left-handed structures for certain values of dielectric permittivity and magnetic permeability when negative-index slabs do not support any guided modes, giving rise to complete two- and even three-dimensional bandgaps.